ExoMars Trace Gas Orbiter & Mars Express : Science update

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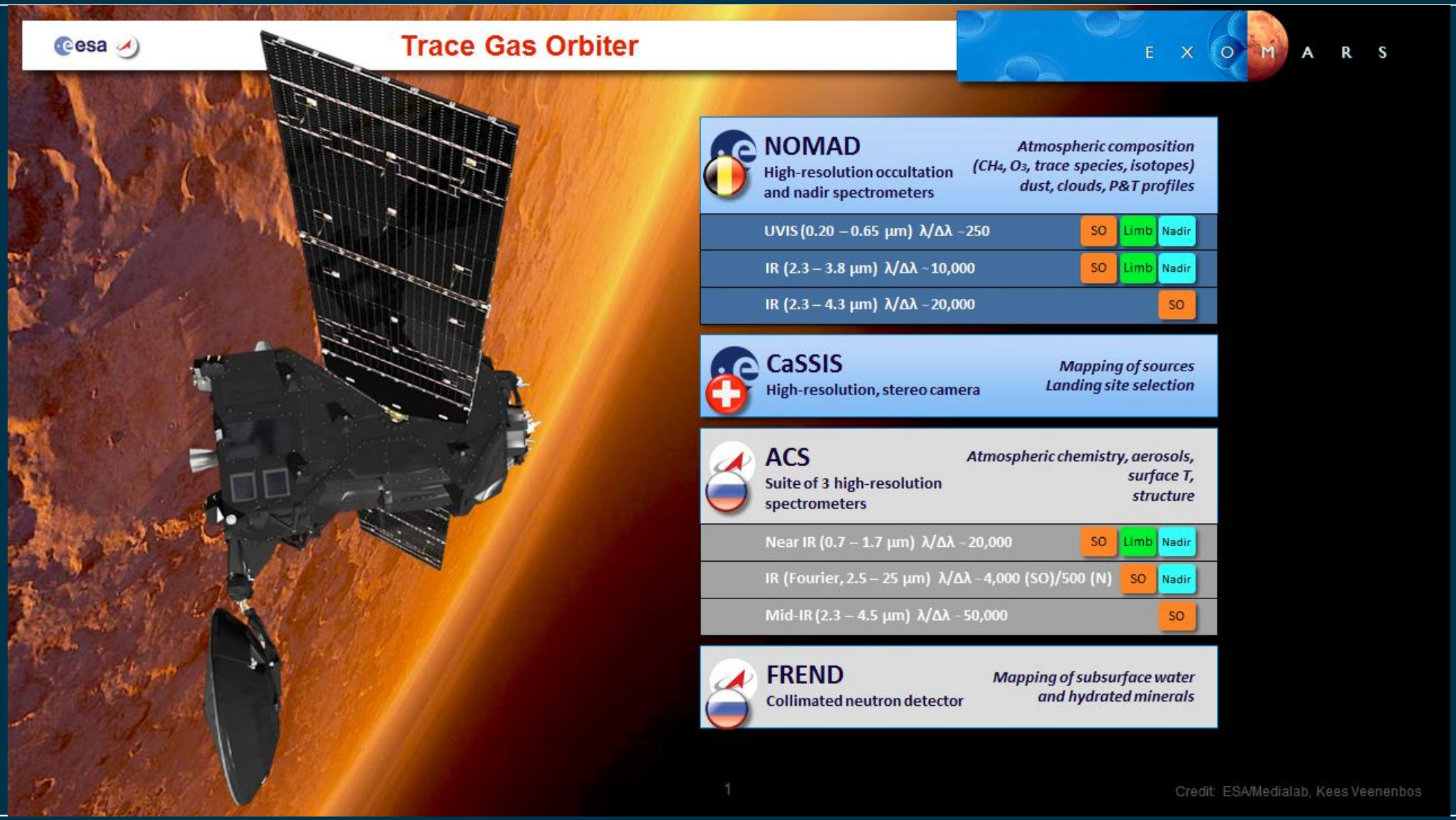
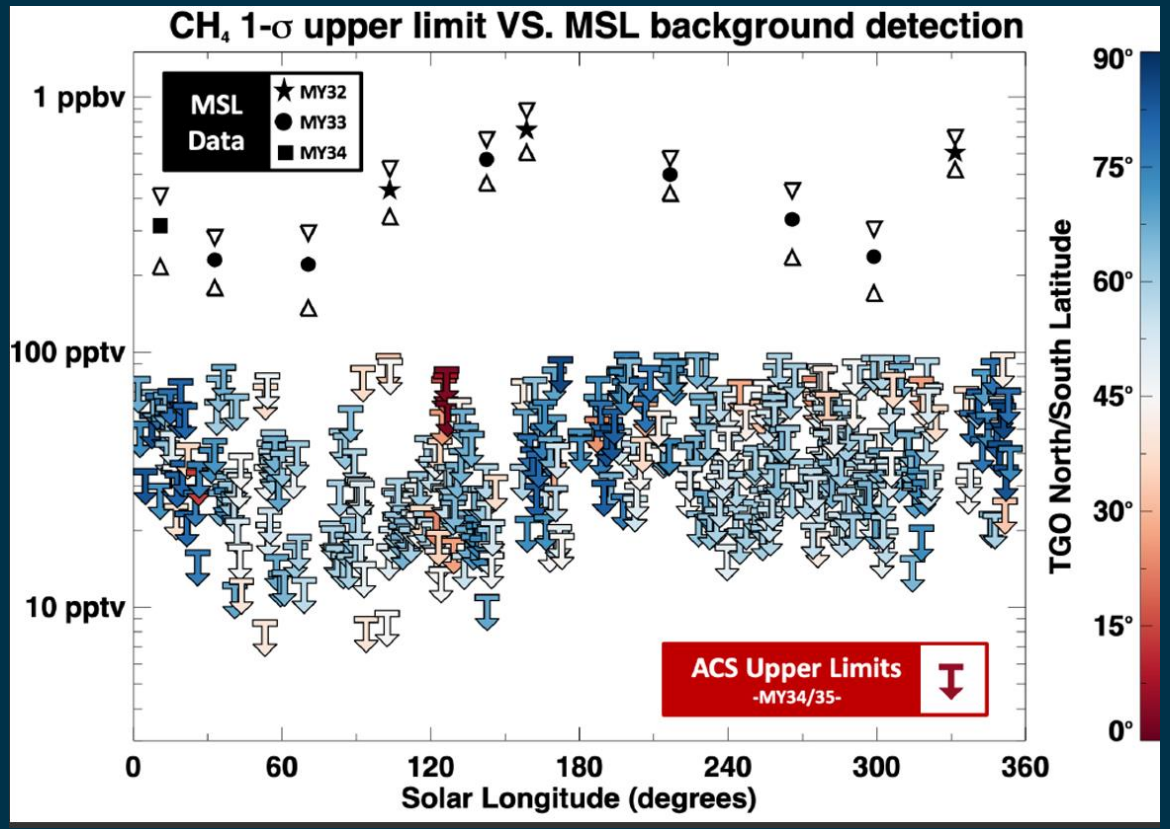
PART I : ExoMars Trace Gas Orbiter



Methane & other biosignature gases – ACS & NOMAD

- **Still no methane**, after a full Martian year of observations.
  - Upper limits down to **20 ppt**, well below levels reported from MSL.
  - Independently measured by ACS & NOMAD instruments.
- **New upper limits reported for many gases** including C_2H_6, C_2H_4, PH_3, SO_2, OCS, H_2S
  - Continuing the search for possible indicators of biological or of volcanic activity.
- Innovative chemical and dynamical modelling ongoing to reconcile the TGO & MSL methane results



Montmessin et al., 2021

Water & escape – ACS & NOMAD

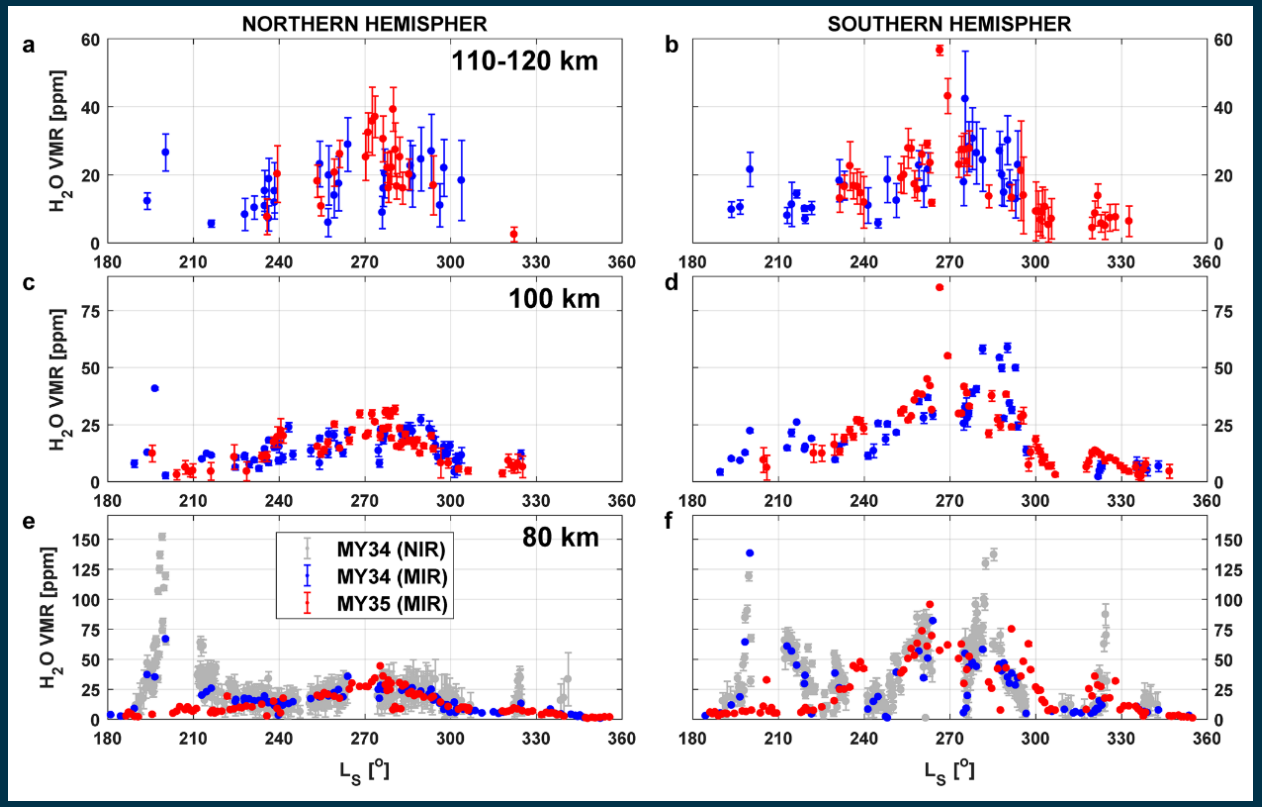
TGO allows unprecedented ability to measure vertical distribution of water up to very high altitudes.

Water escape rate is governed by transport to high altitudes, where it photo-dissociates and escapes.

Regional dust storms are a major contributor to escape (Chaffin et al., 2019, Holmes et al 2021)

But water transport in perihelion season may be more important factor overall than dust storms (Belyaev et al 2021).

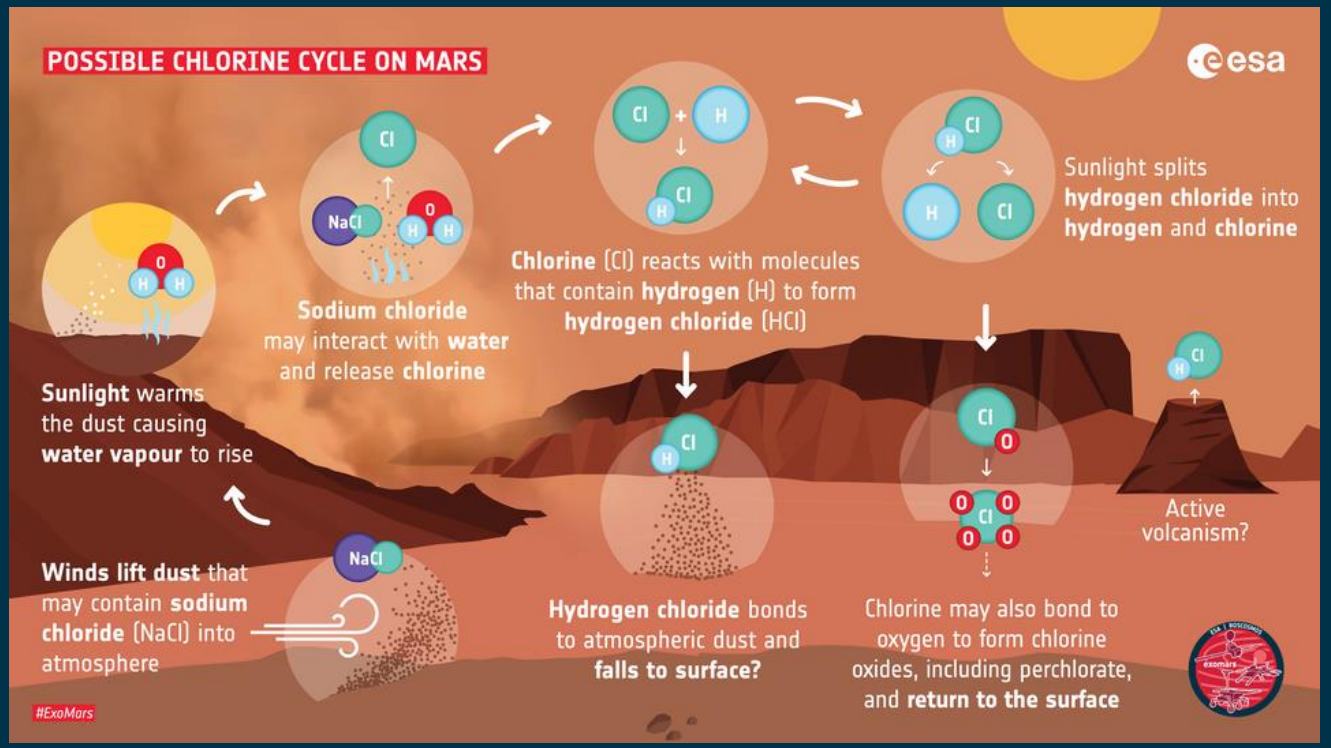
Together, TGO & MAVEN investigations are leading to ever more detailed understanding of water escape.



Belyaev et al., GRL, 2021

TGO Science – HCl – ACS & NOMAD

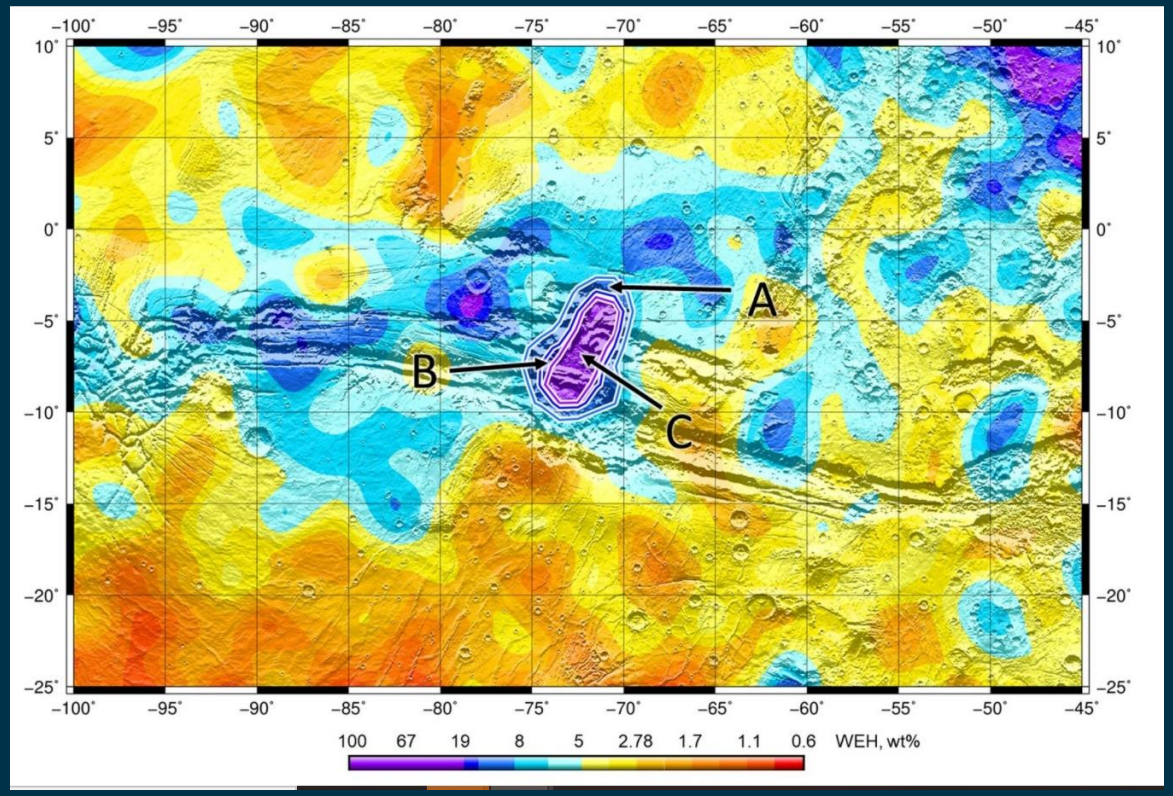
- **First detections of HCl – Korablev et al 2021**
  - HCl abundances are variable, typically in 0 – 5 ppbv range
  - HCl appears linked to water and dust availability, not volcanism (Korablev et al., 2021; Daerden et al 2021)
  - $H^{35}Cl$ / $H^{37}Cl$ ratio mapped, found to be consistent with values from Mars surface (MSL) and from Earth
  - Links to surface materials (such as perchlorates) to be explored.



- **TGO is mapping O_3 , O2, CO , OCS, isotopic ratios and more – *more results to come…***

TGO Science – hydrogen mapping using FREND

- TGO/FREND neutron mapping reveals a region in central Valles Marineris with very high hydrogen abundances.
- The analysis suggests as much as 80% *water ice equivalent hydrogen* in top 1-2 m of surface.
- Some of this H will be in hydrated minerals, but much is likely to be water ice “permafrost”.
- Visible imagery & IR spectroscopy do not show particular composition anomalies here.
- *N.B. FREND calibration paper recently published: Malakhov et al., Cos. Res. 2022*



Mitrofanov et al., Icarus, 2022

TGO Science – hydrogen mapping using FREND

Next steps:

- This apparent high H abundance confounds expectations; more work is needed to understand its cause.
- FREND has revealed more low-latitude H-rich “oases” to be investigated.
- Neither Curiosity, Perseverance or Rosalind Franklin rovers appear to be in these H-rich regions
- Mars Ice Mapper will allow follow-up investigations of near-surface ice with much higher spatial resolution.

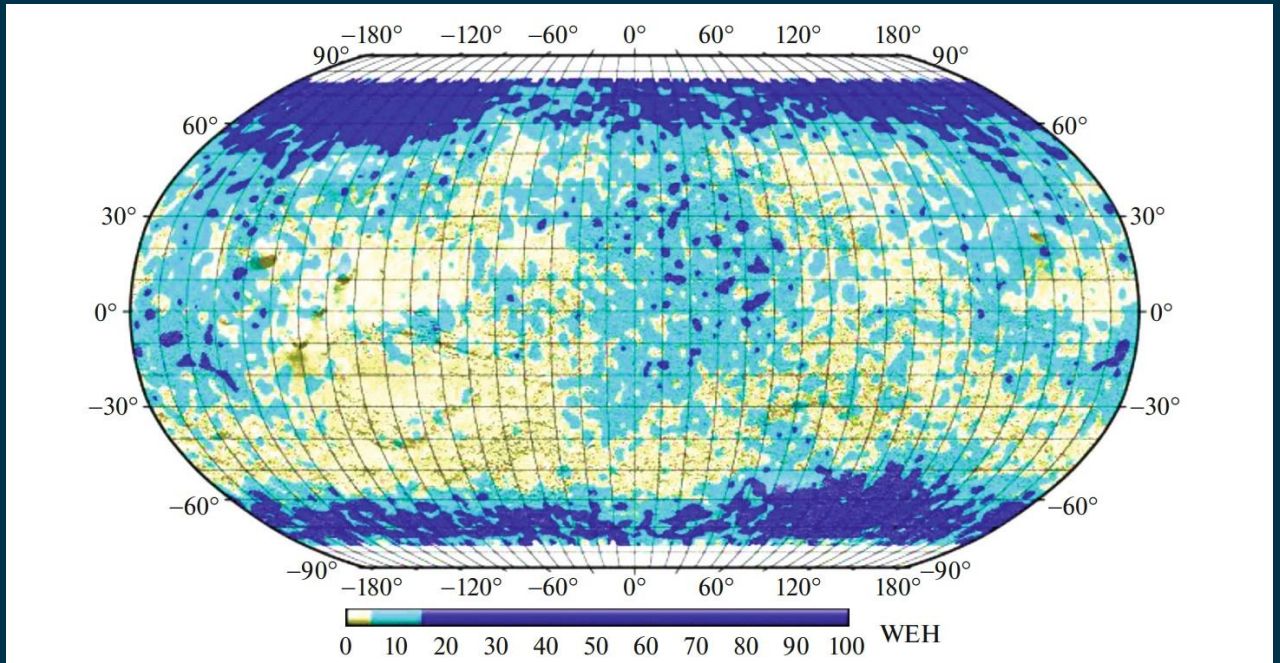
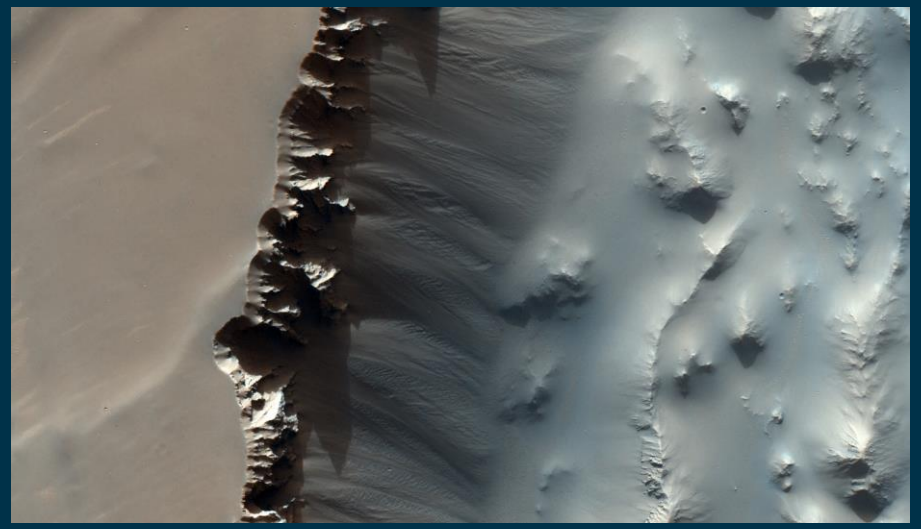


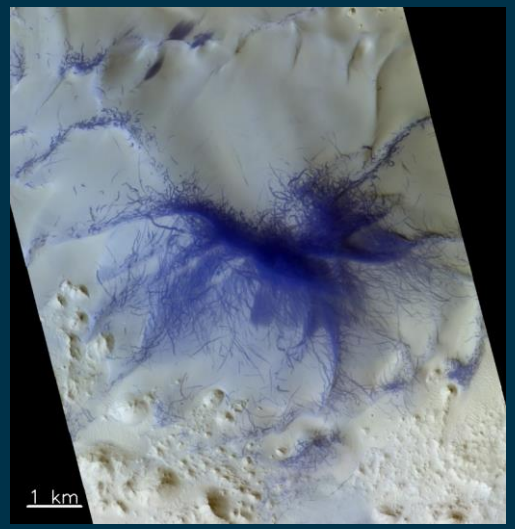
Fig. 3. Martian surface hydrological types. The areas with water content of 0–5% WEH (beige), 5–15% WEH (blue), and above 15% WEH (dark blue) are highlighted with color.

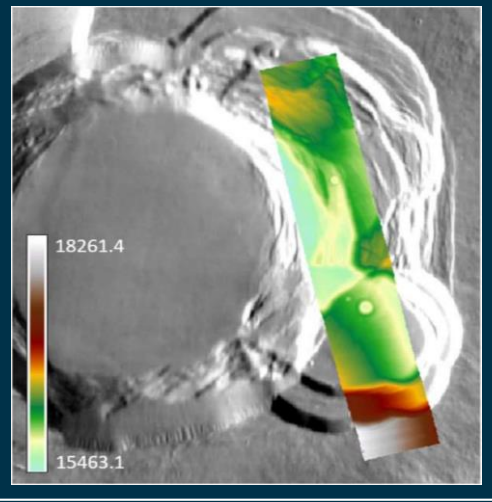
Malakhov et al., Ast. Lett., 2020

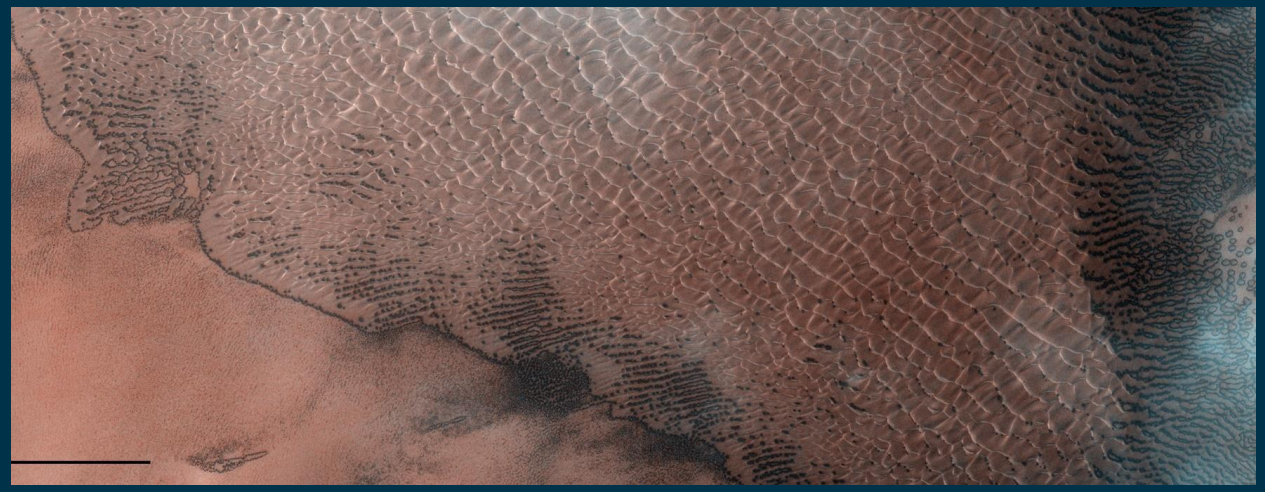
TGO – CASSIS imager

- CASSIS continues to obtain beautiful targeted imagery at 5 m resolution.
- Data pipelines, mosaicking, DTM processing are excellent.
- DEMs processed in Padua - cassis.oapd.inaf.it/archive/ (Simioni et al)
- Collection of 11 calibration, pipeline & early results papers in *Planetary & Space Science*





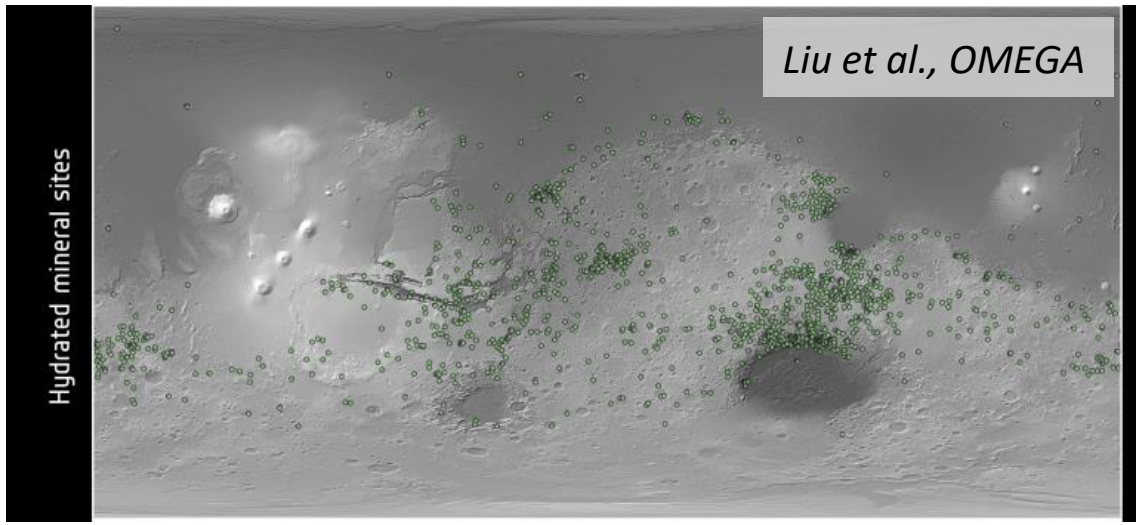


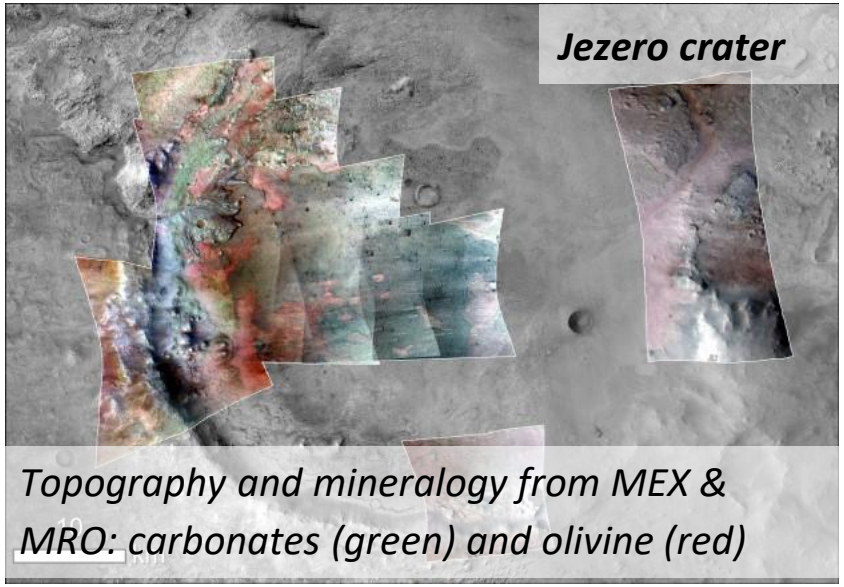


PART II : Mars Express

1. Geology, interior and history

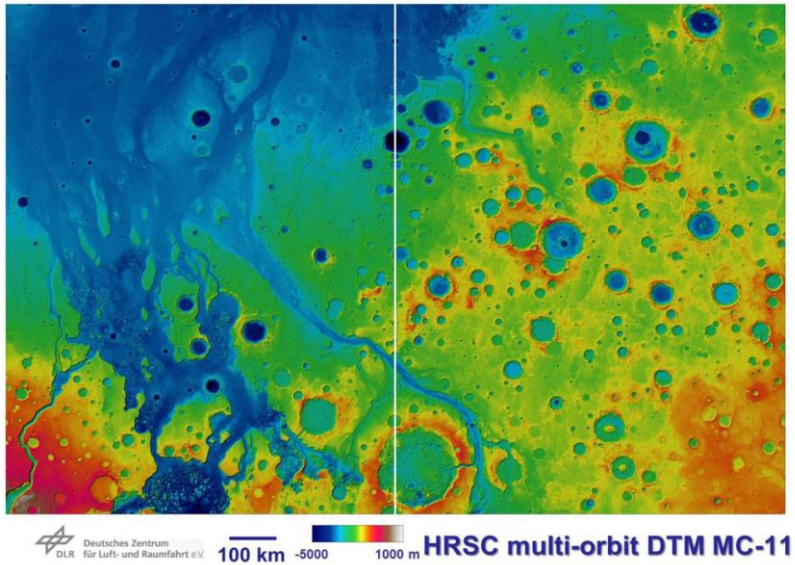
- Global map of **hydrated minerals from OMEGA** with resolution of 200 m/px (Liu et al 2021)
- **HRSC Digital Elevation Models** -
  - Campaign to 'fill gaps'; **98.9%** of the planet now imaged
  - **Multi-look 50m DTMs** being created for the whole planet
- **Landing site characterization** for Oxia Planum & Jezero Craters (HRSC, OMEGA)





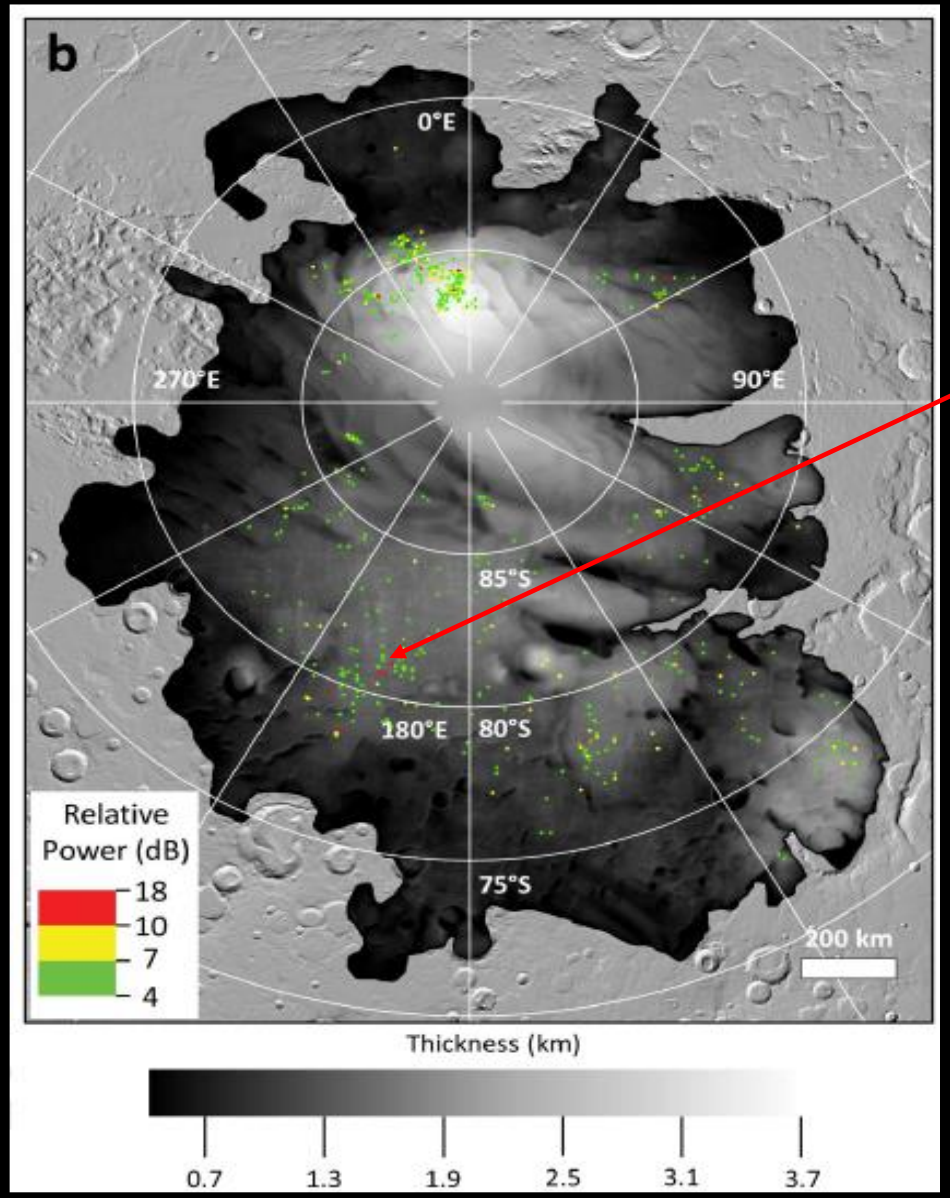
Topography and mineralogy from MEX & MRO: carbonates (green) and olivine (red)

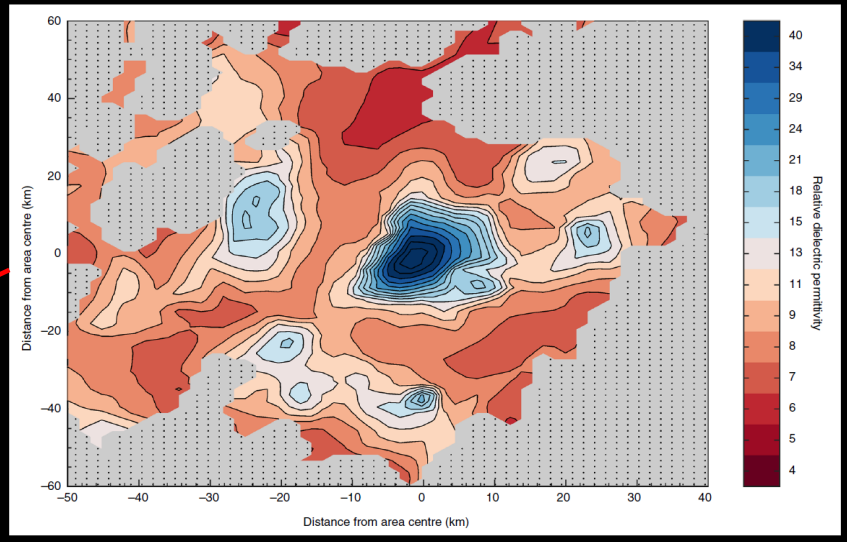
HRSC Mars Chart MC11 (East and West)



HRSC multi-orbit DTMs for MC-11-E (Oxia Palus, East) and MC-11-W (Oxia Palus, West). Extent: 2663 km (E-W, at the equator), 1780 km (N-S), grid spacing 50 m.

Bright MARSIS radar echoes from the SPLD

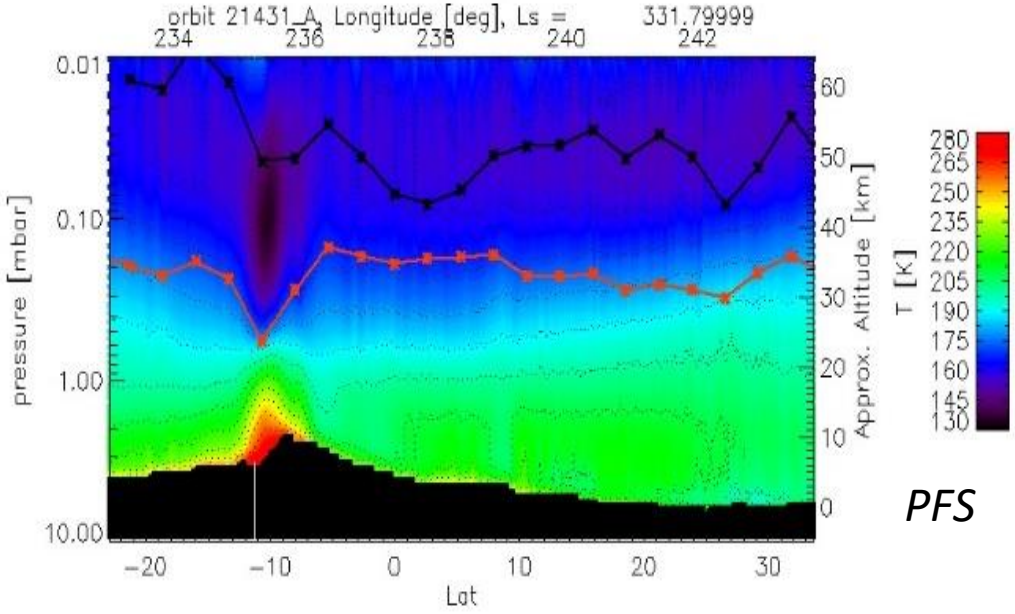




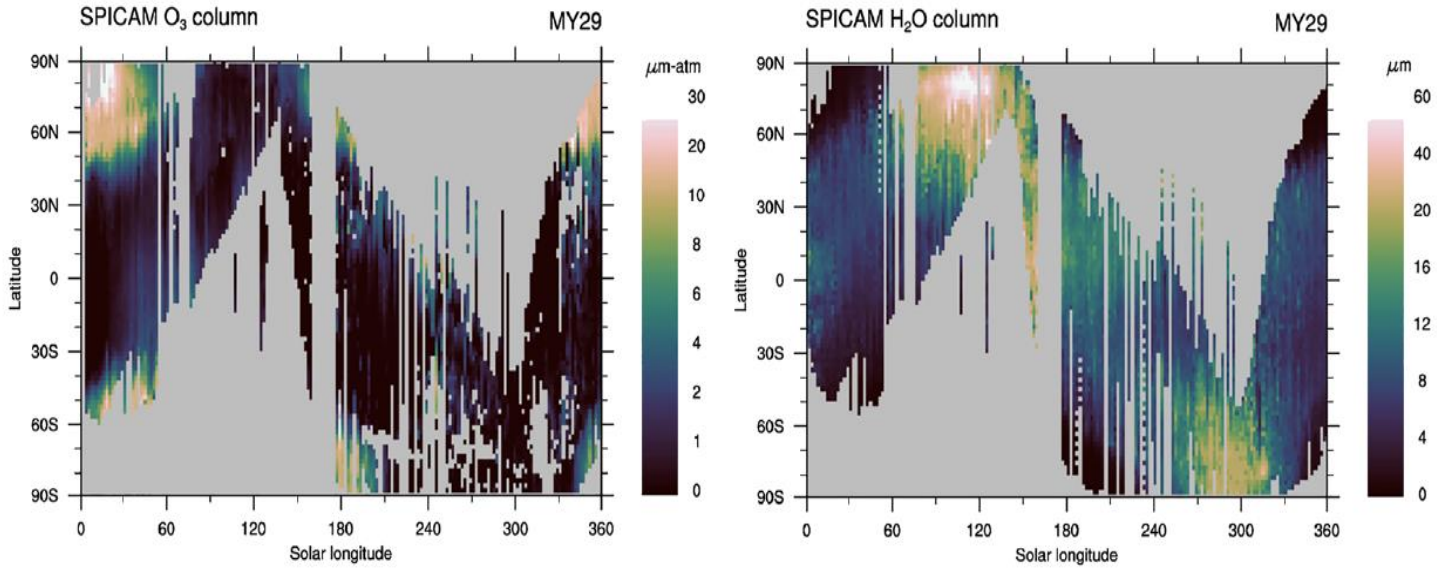
- Bright radar basal reflections detected by MARSIS; found to be widespread (*Khuller & Plaut, 2021*); MARSIS team suggests liquid brines (*Orosei et al., 2018; Lauro et al., 2020; Mattei et al, EPSL 2022*)
- Other possibilities: Clays, saline ice, metal-bearing minerals, ice-covered volcanic materials (*Smith et al., 2021, Bierson et al., 2021, Grima et al., 2022*)
- *Debate is very much ongoing!*
- *New MARSIS software to allow more extensive sounding*

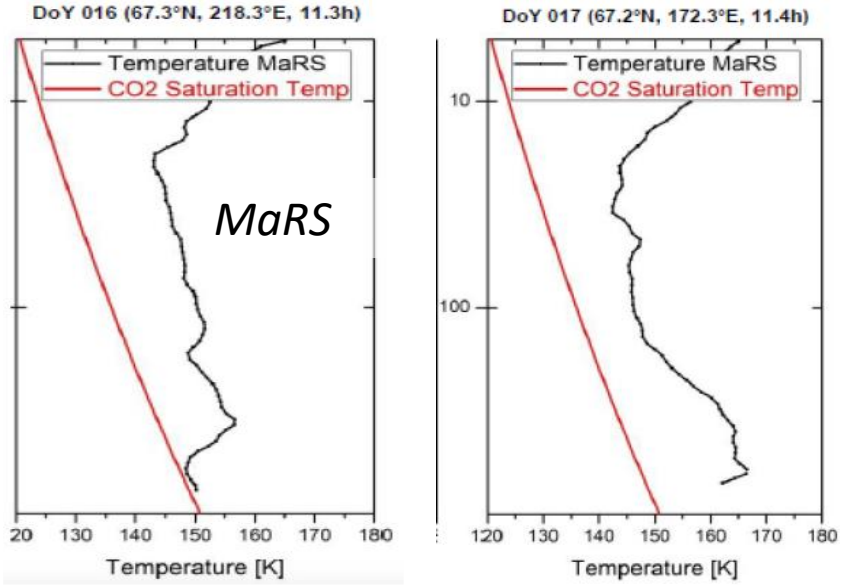
2. Meteorology and climate

- O_3 – H_2O anticorrelation (*Lefevre et al., 2021*)
  - *Dust controls T ; T controls H_2O ; H_2O controls O_3*
  - *Collaborative analyses from MEx, TGO, and modelling teams*
- Cross-orbit scans over prominent topography (PFS)
- Temperature structure over almost 10 Martian years (MaRS)



PFS

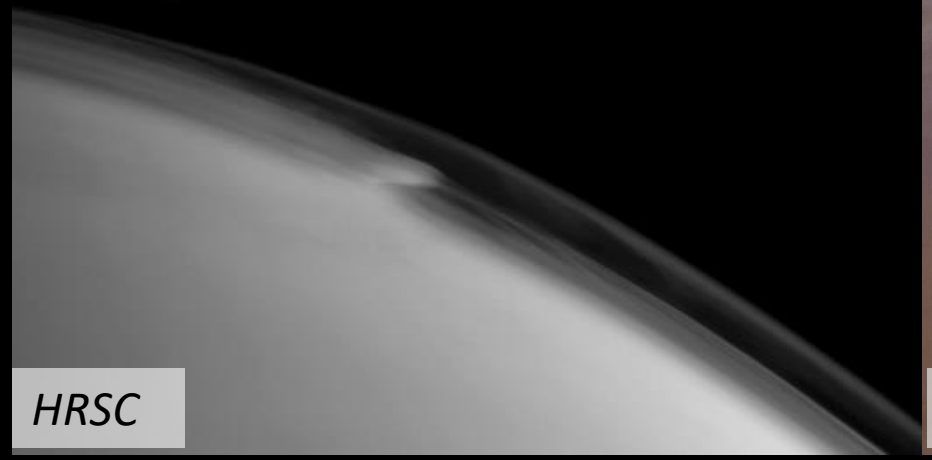


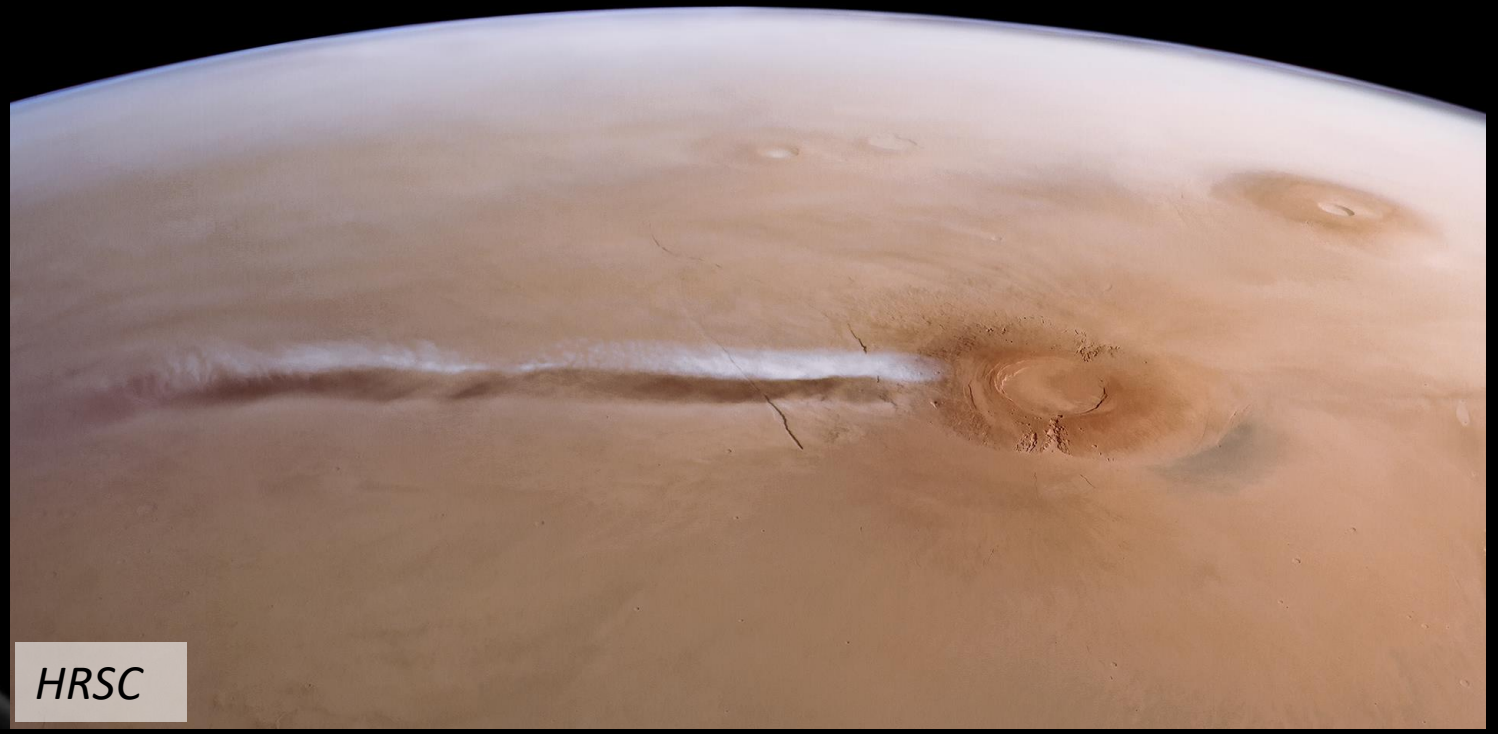


MaRS

Elongated orographic cloud at Arsia Mons

- Horizontal extension up to 2000 km
- Altitude 40-50 km
- Rapid daily cycle
- *VMC : Re-purposing of engineering camera for science*

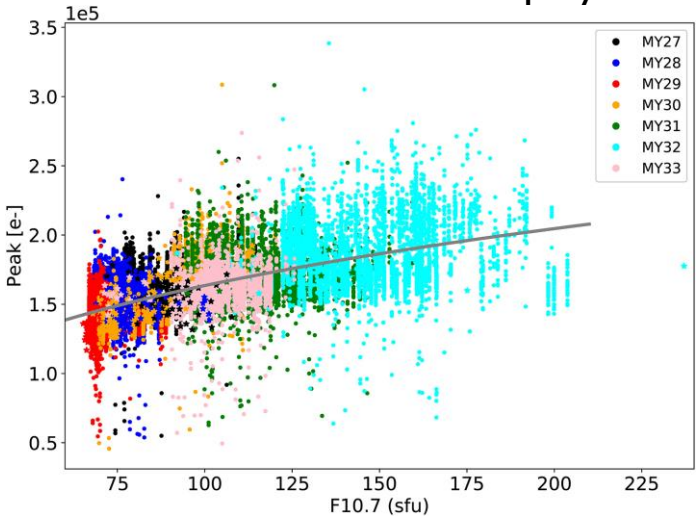




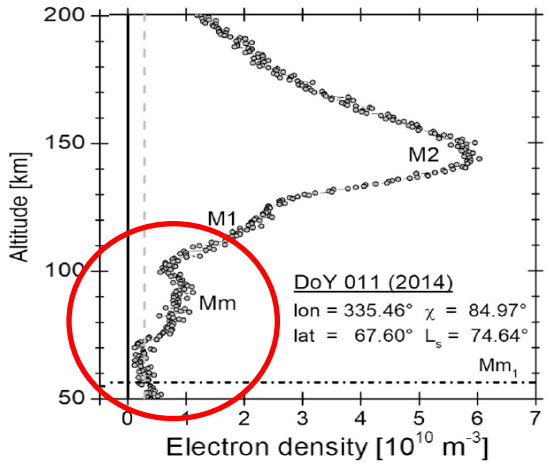
Hernández-Bernal et al., 2020

3. Aeronomy and plasma environment

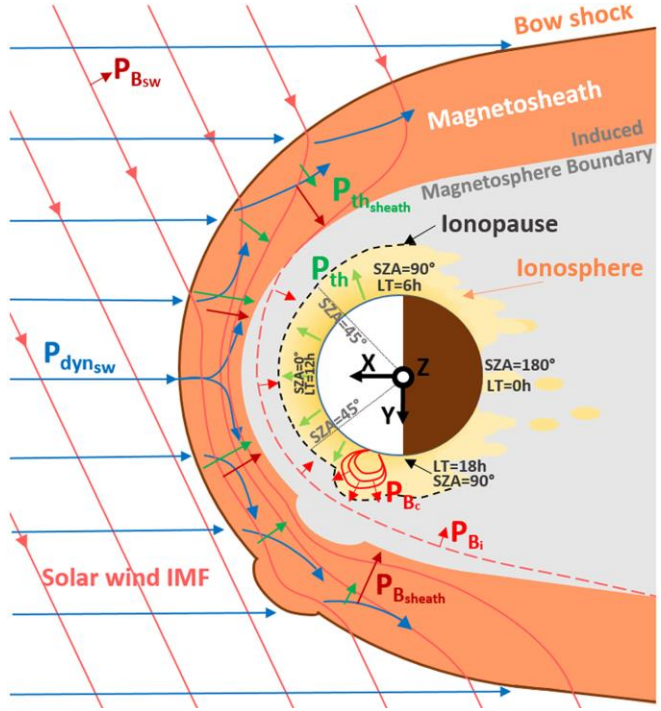
- MEx' high apoapsis (> 10,000 km) gives it an unequalled position outside the bow shock to **monitor upstream solar wind** conditions
  - E.g. Sanchez-Cano et al 2021 **study of ionopause formation** – combining MEx & MAVEN data
- **Long mission duration** allows disentangling different dependencies (see e.g. Gonzalez-Galindo et al 2021)
  - E.g. study of 'quiet' dayside ionosphere structure (Peter et al., 2020)
- MEx & VEx ASPERA payloads allow **Mars-Venus comparison**

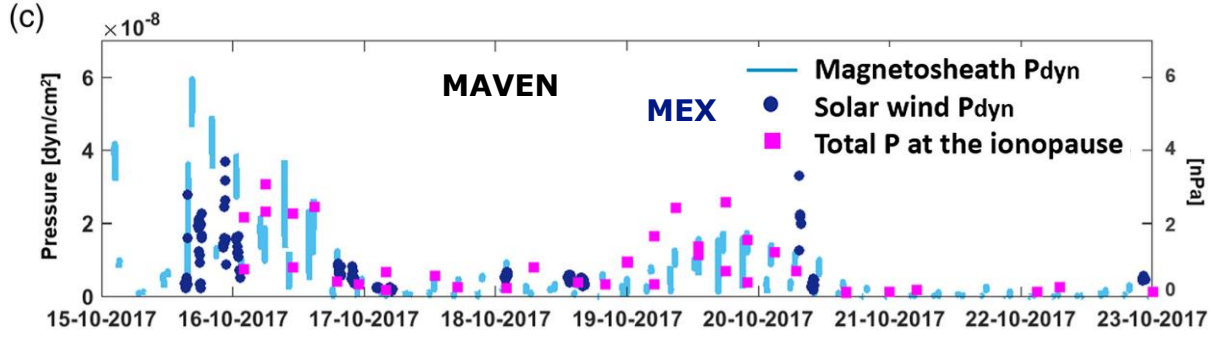


Gonzalez-Galindo et al., 2021



Peter et al., 2021

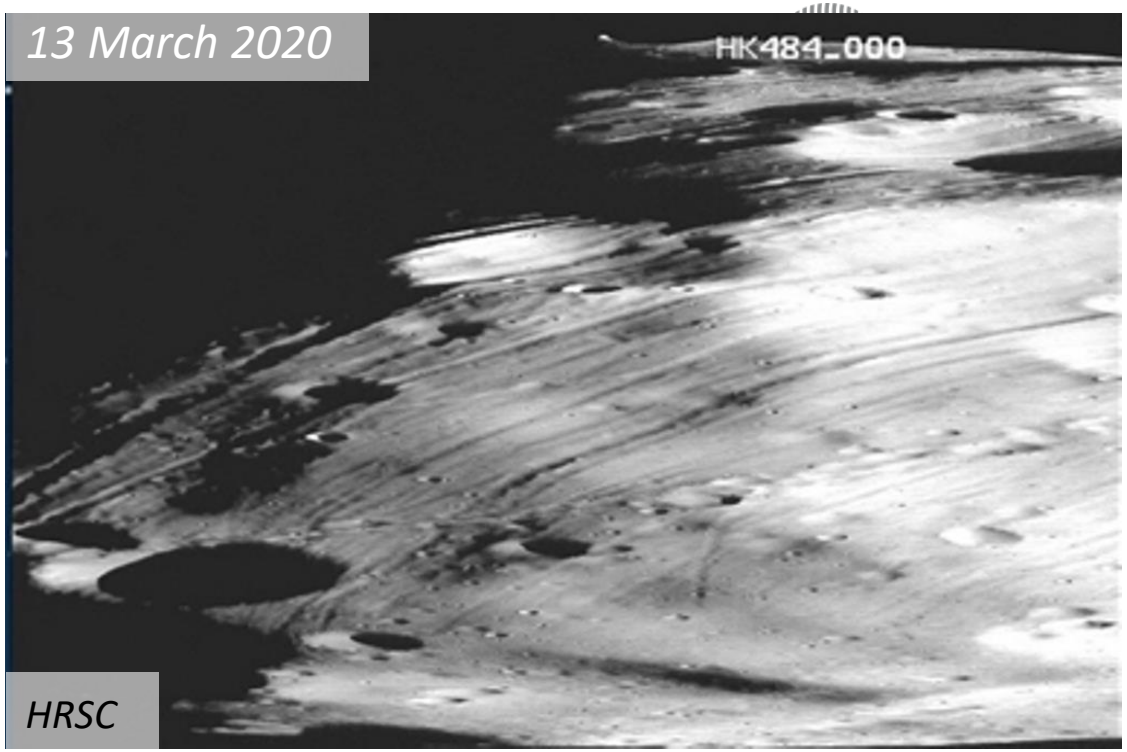


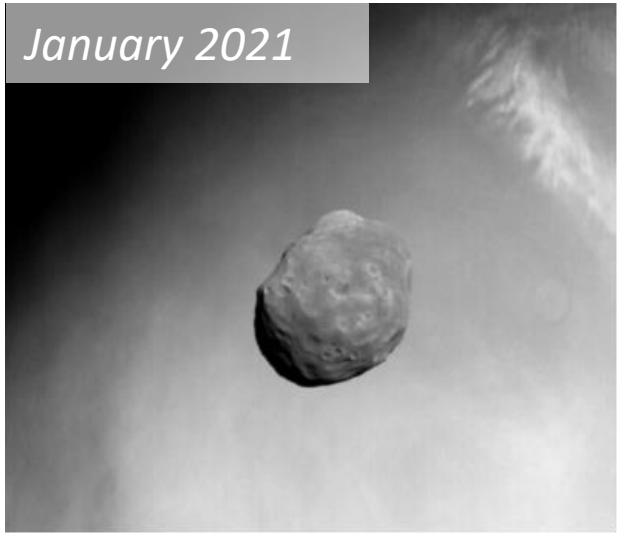


Sanchez-Cano et al., 2021

4. Phobos investigations

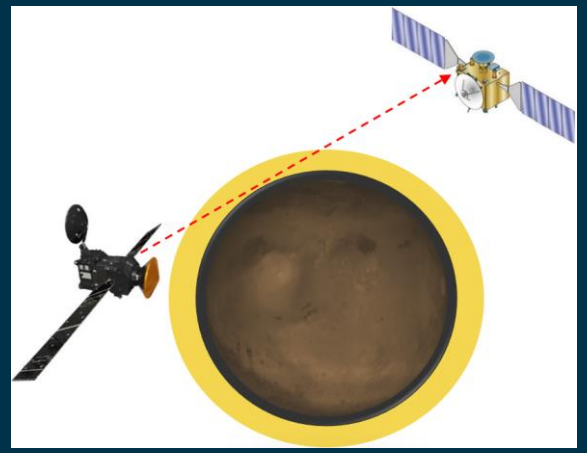
- In 2019-2021 ~20 flybys of Phobos at <1000 km: augmenting the spatial and spectral coverage, constraining the surface properties and refining ephimerides.
  - *Paving the way for the MMX mission*
- ASPERA confirms detection of backscattered protons from the solar wind (*Futaana et al 2021*)
- *New subsurface Phobos MARSIS sounding mode will allow far longer sounding operation.*

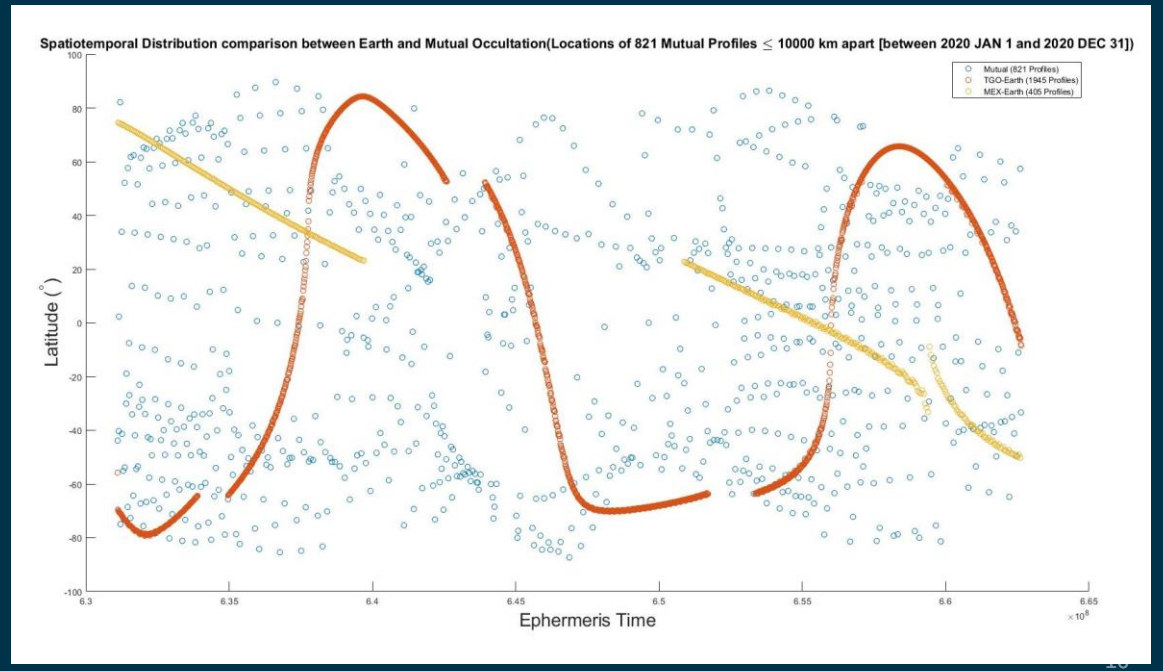




MEX – TGO : mutual radio occultations

- MEX UHF radio signal is received by TGO.
- Signal is refracted as it passes through the atmosphere.
- Allows **vertical profiling of electrons in the ionosphere**. Complements MEx/ASPERA in situ observations.
- Similar to the traditional MEx-Earth occultations, but allows far more frequent and evenly distributed profiling.
- **Preliminary tests look promising, so we are looking to implement this operationally in 2022.**





TGO & MEX mission status

Mission status

- A recent technical review concluded that both spacecraft are healthy and fully capable of operating for at least in the 2023 – 2025 period.
- With some exceptions (eg SPICAM UV, OMEGA IR, ACS/TIRVIM), payloads nominal and ready for lots more science.
- TGO science output is ramping up; MEx output is steady as it enters its 18^{h} year at Mars (> 1400 publications to date).

As well as their scientific investigations, TGO & MEx have been providing excellent data relay service.

- TGO has averaged more than twice its foreseen data return requirement of 8 Gb/day.
- TGO has relayed much of MSL & Mars2020 data, using the NASA-contributed Electra radio.
- MEx has been testing data relay for China's Zhurong rover
- Looking forward to providing relay for ExoMars rover & surface platform from June 2023.

ESA funding of MEX, and of TGO science operations, is secured until end of 2022.

- Mission extension request for 2023 – 2025 is being considered in coming months.

Proposals for collaborative investigations with MEx and/or TGO are always welcome!